Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

UNITED STATES DEPARTMENT OF AGRICULTURE
MISCELLANEOUS CIRCULAR NO. 41

WASHINGTON, D. C. AUGUST, 1925

ESTIMATING THE QUANTITY OF GRAIN IN BINS

WITH CHART REDUCING THE NECESSARY COMPUTATIONS

LIBRARY
RECEIVED
★ SEP 1925 ★
U. S. Department of Agriculture

BY

E. N. BATES
Investigator in Grain Handling, Grain Division
Bureau of Agricultural Economics

WASHINGTON
GOVERNMENT PRINTING OFFICE
1925

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
5 CENTS PER COPY

UNITED STATES DEPARTMENT OF AGRICULTURE

MISCELLANEOUS CIRCULAR NO. 41

WASHINGTON, D. C. AUGUST, 1925

ESTIMATING THE QUANTITY OF GRAIN IN BINS[1]

WITH

CHART REDUCING THE NECESSARY COMPUTATIONS

By E. N. Bates

Investigator in Grain Handling, Grain Division, Bureau of Agricultural Economics

---

CONTENTS

Page
Observations to be made 2
Description of chart and directions for its use 2
    Examples illustrating use of chart 4
        Estimates of bin capacities 4
        Adjustment for test weight of wheat and packing effect 6
        Estimating the equivalent depth of hoppers 7
Definitions of terms and formulas 7
Chart in cover pocket.

Mill and elevator operators, warehouse inspectors, and traveling auditors have frequent occasion to estimate the quantity of grain in stock in bins. In the absence of a running record of additions and withdrawals they must resort to detailed computations or to rough estimates; but very close estimates of stocks on hand at any time may be made by means of a chart drawn for the purpose. Such a chart and instructions for using it are presented in this circular. Use of the chart eliminates most of the computation otherwise necessary and reduces the work of estimating stocks on hand to a few observations, most of which need be made only once for any bin, and to simple addition and multiplication.

The number of legal bushels of wheat[2] in a bin depends on the dimensions and shape of the bin, the depth of the wheat in the bin, and the test weight of the wheat. The estimate of quantity of wheat in a bin is therefore made in two parts: (1) Determination of the space occupied by the wheat in terms of standard Winchester bushels (1.2445 cubic feet); and (2) adjustment made in the estimate for differences in the test weight per bushel, and for packing effect. A legal bushel (60 pounds) of wheat of test weight higher than 60 pounds per bushel occupies less space than the standard measured bushel, and a legal bushel of wheat of test weight lower than 60 pounds per bushel occupies more space than the standard bushel. As the depth of the wheat in a bin increases the weight of wheat above packs that below into smaller space. The amount of this packing has been determined experimentally to average 4.85 per cent of the test weight per bushel.

---

[1] S. W. Mendum, associate agricultural economist, gave valuable editorial assistance in the preparation of this material for publication.

[2] All statements regarding capacity of bins apply equally to all other grains as well as to wheat; but the adjustments for different test weights above and below the standard, and for packing effect, are here shown for wheat only.

OBSERVATIONS TO BE MADE

The capacity of a bin in standard bushels is the volume in cubic feet divided by 1.2445. The space occupied by the wheat in a bin partly full is the same as the capacity of a full bin of the same shape and of the depth of the wheat standing in it.

The volume of a bin is found by multiplying the area of the base, or horizontal cross section, by the mean depth. Most deep grain bins are of uniform cross section above the hopper, and are circular, square, or rectangular. Sometimes the space between four circular bins built in a group so that the walls touch is used as a bin called an "interstice bin." Hoppers are either symmetrical with the outlet at the center or unsymmetrical with the outlet at the side. The "mean" depth to be used in the estimates is the distance between a level surface at the top of the bin (or of grain in the bin) and the bottom of the bin, with an allowance (the equivalent depth of the hopper) for the reduction in volume due to the sloping sides of the hopper.

The observations to be made to find the capacity are therefore the shape of the bin, the shape of the hopper, the dimensions of the cross section of the bin, depth of bin, and equivalent depth of hopper. These observations of bin and hopper dimensions need be made only once for each bin. The depth of grain in the bin must of course be measured each time an estimate of quantity is desired. The test weight of the wheat in the bin at the time of the estimate must also be known. With symmetric hoppers the "equivalent depth" is one-third the vertical depth of the hopper. The determination of equivalent depth of irregular hoppers is given later in the circular. The following discussion assumes that "depth of bin" (and "depth of wheat") includes the "equivalent depth" of the hopper—that the "mean depth" of bin or of wheat is to be used in the estimates.

DESCRIPTION OF CHART AND DIRECTIONS FOR USE

The chart attached to this circular is designed to give without computation the capacities of bins of all sizes and shapes up to circular bins 23 feet in diameter (inside measurements) and 30 feet deep (32 feet deep for smaller bins). It does this by means of lines and scales. All the computations have been made in determining the position of the lines. The capacities of bins of greater depth than 32 feet may also be readily obtained by taking a fraction of that depth coming within chart limits, selecting the lines indicated by the observations previously made, following them to the point of intersection and reading the scale of capacity or of quantity at the side of the chart.

There are two vertical scales, A and A', representing capacities of bins and quantities of wheat up to 10,000 measured bushels. The main divisions are made at each 500 bushels with 10 subdivisions in each. Readings may be made exactly, therefore, to the nearest 50 bushels and can be estimated still closer. All results may be taken from these scales. The two scales are equal, and readings may be made from either, but it is convenient to use scale A for finding bin capacities and scale A' for estimating the quantity of wheat in a bin.

There are three horizontal scales, B, C, and D, the divisions running vertically. These represent the area of the cross section of the bin. Scale B is in terms of square feet of cross-section area and has main divisions for each 25 square feet of area up to 425 square feet and subdivisions for each 2.5 square feet. This scale is general in its applications, but requires computation of the area in square feet, and need be used for round and square bins only when the special scales C, for square bins, and D, for circular bins, are not convenient. The divisions of scale C, for use with square bins, are so placed that only the inside length of the side need be observed. The divisions of scale D, for use with circular bins, are so placed that only the inside diameter in feet need be measured, avoiding the necessity of computing the area from the formula $\left(\text{area}=\frac{3.1416\times D\times D}{4}\right)$. Note that the distances between divisions on scale B are equal, and that those on scales C and D increase from left to right as the dimensions in feet increase. These increases in distances between divisions represent increases in areas.

There is a set of diagonal lines running from the lower left-hand corner upward to the right, one for each foot of depth of bin from 4 to 32 feet. The point of intersection of any of these lines with any of the vertical lines gives the capacity of a bin of the shape and depth selected, read in terms of bushels from the scale (A) on the right. Use of a ruler helps in following the vertical and horizontal lines, especially in reading the scale.

There is also a set of diagonal lines running from the lower right-hand corner upward to the left. These are for use in estimating the quantity of wheat (legal bushels) in the bin, after the space occupied by the wheat has been found. They consist of (1) a reference line (heavy) and (2) a line for each pound of test weight per bushel from 54 pounds to 64 pounds. The "60-pound line" is not the "reference line" because 10,000 bushels by weight of 60-pound wheat in a deep bin will be packed into a measured space of approximately 9,525 bushels.

Having found the bin capacity occupied by the wheat, the estimated number of legal bushels of wheat is obtained by finding the intersection of the scale line for the number of bushels by capacity with the proper line for the test weight per bushel, and proceeding vertically up or down to the "reference line" and reading its position on the scale to the left (scale A'). A reversal of this process will show how much space a known weight of wheat of given test weight per bushel will occupy.

For bins deeper than 32 feet, a simple division by 2 or 3 will bring the depth within the limits of the chart and the volumes of the portions may be found and added. Similarly, bins of greater cross-section than 425 square feet can be estimated through division to meet the limits of scale *B*.

Readings from the chart, if carefully made, will ordinarily have less error than the measurements of the depth of wheat. An error of 4 inches in measuring the mean depth of grain in a 22-foot circular bin means an error of about 100 bushels, whereas the chart may be read closer than the nearest 25 bushels. There may be other slight errors incident to lack of uniformity in the test weight of the wheat and to variation of packing effect at different depths, as only the average was used in drawing correction lines.[3] Mistakes in computation are practically eliminated, if observations are close and the proper lines on the chart are used.

The examples which follow further illustrate the use of the chart by specific cases:

EXAMPLES ILLUSTRATING USE OF CHART

ESTIMATES OF BIN CAPACITIES

(1) *Circular bins.*—What is the bushel capacity of a circular grain bin 22 feet in diameter with a mean depth of 18 feet? (Equivalent depth of hopper included as part of the 18 feet).

This bin has a capacity of 5,500 bushels found as follows: Using the scale for circular bins (scale *D*) select the heavy vertical line at 22. All points on this line apply to a circular bin of 22 feet inside diameter. It is crossed (or cut) by the depth diagonal lines, only one of which, however, that marked 18, applies to this case. The point of intersection indicates the capacity of the bin and is read in terms of bushels on the vertical scale at the right (scale *A*). Follow the fine line across to the scale and read the answer—5,500 bushels.

Had the mean depth of this bin measured 54 feet instead of 18 feet the bushel capacity would have been found in exactly the same manner, as dividing 54 by 3 gives 18, which is a depth provided for in the chart, and multiplying the capacity already found for the one-third portion (5,500 bushels) by 3 gives 16,500 bushels as the answer. Just as easily, the 54 feet of depth might have been divided by 2, the capacity for 27 feet of depth on the same vertical line read (8,250), and multiplied by 2 again, giving the same result, 16,500 bushels.

When the depth does not run in even feet, two methods of working the problem are suggested. Suppose the mean depth of the bin in the problem above had been 18.7 feet instead of an even 18 feet. The point 18.7 lies seven-tenths of the vertical distance on the line (22 feet vertical) above the point 18, toward the point 19, and its position may be estimated closely enough for some purposes. The fraction is rather difficult to estimate with precision. In this case the reading would appear to be about 5,700 bushels (for 18.7 feet of depth). A more precise method of finding the capacity of the bin at 18.7 feet depth is to read the bushel capacity for 7 feet (on the 22-foot vertical) which is 2,150 bushels, and use one-tenth of it, or 0.7 feet, giving 215 bushels as the amount to be added to the reading for 18 feet, giving 5,715 as the bushel capacity for 18.7 feet in this 22-foot diameter circular bin.

Sometimes the fraction of a foot of depth is more conveniently obtained in inches. In such a case the special diagonal for 100 inches of depth has been added and may be used to find the quantity to be added for each inch of depth. Read the bushel capacity for 100 inches, point off two decimal places, and multiply by the number of inches in the fraction.

(2) *Square bins.*—The capacity of a square bin with a 17-foot side and a mean depth of 81 feet 9 inches is desired. The capacity is approximately 19,000 bushels, found as follows.

---

[3] The determination of packing effect was made by George P. Bodnar, of the grain division, as a result of a study involving 310,000 bushels of wheat the moisture content of which ranged from 9 to 12 per cent. The average packing effect amounts to 4.85 per cent of the average test weight per bushel for wheat in deep bins.

In this case the vertical line marked 17 on the scale for square bins (scale *C*) is used throughout. The depth of this bin is not represented on the chart, and must be divided. It is convenient to read the capacity of this bin as three times the capacity of a bin 27 feet deep and add the capacity of the 9 inches. The 27-foot depth diagonal line crosses the 17-foot vertical line at 6,275 bushels of the scale. Three times this capacity is 18,825 bushels for the even 81 feet. The addition for 9 inches is as before found by means of the special diagonal for 100 inches of depth; the reading is taken as 1,940 bushels, or dividing by 100, 19.4 bushels for each inch of depth, and gives 174.6 bushels for the 9 inches. The bin therefore is figured at 18,999.6, practically speaking, 19,000 bushels. (NOTE.—Little significance should be accorded to the units digit in these estimates, and the tens digit may often be somewhat in error.)

(3) *Rectangular bins.*—Assume a bin 13 feet by 21 feet, with a mean depth of 63.4 feet. What is its capacity in bushels? The capacity is 13,910 bushels, found in the following manner:

This bin being neither round nor square, the vertical line to use must be obtained from scale *B* at the bottom of the chart. The area of a cross section of this bin is 273 square feet. No subdivision line is drawn at 273. The closest indicated is 272.5, which will be used for reference (the exact line wanted would lie slightly to the right). The depth 63.4 feet must be split, and dividing by 2 will serve, making it necessary to read for 31.7 feet as half of the bin capacity. The reading for 31 feet on the vertical for 273 feet is approximately 6,800 bushels. The reading at 7 feet is approximately 1,550 bushels, one-tenth of which added to the 6,800 previously read gives 6,955 bushels for 31.7 feet, half the bin, and 13,910 for the full bin. Figured out mathematically the exact capacity is 13,908 bushels.

(4) *Bins with cross-sectional area greater than the limits of the chart.*—Find the capacity of a circular bin 30-foot diameter, 60 feet deep.

In this case it would be convenient to work with a circular bin of one-half the required diameter and one-half the given depth, or a 15-foot diameter bin 30 feet deep. The areas of similar figures vary as the square of similar dimensions, so the resulting capacity for a 15-foot diameter bin must be multiplied by 4 to equal the capacity of a 30-foot diameter bin. As 30 feet is half the required depth, we must multiply by 2 to get the total capacity. Hence, the capacity of a 15-foot diameter bin 30 feet deep, which is 4,260 bushels, must be multipled by 8 to get the capacity of a 30-foot diameter bin 60 feet deep. This gives 4,260×8=34,080 bushels. Square bins greater than 20 feet on a side may be handled in the same manner.

Rectangular bins with a cross-sectional area greater than 425 square feet should be so divided as to bring the fractional area within the limits of scale *B* and the result multiplied to give the result desired for the original cross-sectional area.

(5) *Interstice bins.*—Most interstice bins are formed by the regular placing of four tangent circular bins of equal diameter with centers at the corners of a square, the side of which is equal to the inside diameter of the bins plus the thickness of one wall. Where the walls are relatively thin, as in circular steel tanks, the thickness of the wall may be disregarded without causing serious error. If the thickness of the wall is disregarded, the area of the interstice bin formed by four regularly placed equal circular bins is 0.273 of the area of one of the bins. Where the interstice bins are regularly formed from four concrete bins of necessary wall thickness, the ratio of interstice-bin area to circular bin area changes with both the diameter of the bins and the thickness of the walls. The factors to use in estimating capacity of interstice bins formed by circular concrete bins have been worked out for walls of 6 to 9 inches thickness and bins 7 to 23 feet inside diameter. (See Table 1.)

An interstice bin formed by four circular concrete bins 20 feet in inside diameter, regularly placed, is 63 feet deep and the walls of the bins are 8 inches thick. What is its capacity?

As in example No. 1 (p. 4), the capacity of one of the circular bins 20 feet in diameter and 63 feet deep is found to be 15,900 bushels. From Table 1, the factor to use for reducing circular-bin capacity to interstice-bin capacity is 0.236, found on the line for 20-foot bin diameter and in the column for 8 inches wall thickness. The capacity of the interstice bin is therefore 15,900×0.236 or 3,752.4 bushels.

TABLE 1.—*Factors to be used in determining volume of interstice bins*

Diameter of circular bins (feet)	Thickness of concrete walls (inches)			
	6	7	8	9
7	0.203			
8	.212			
9	.218			
10	.222	0.217		
11	.226	.220		
12	.229	.223		
13	.231	.226	0.221	
14	.233	.229	.223	
15	.236	.231	.225	
16		.233	.228	0.222
17		.235	.230	.225
18		.237	.232	.227
19		.239	.234	.229
20		.240	.236	.231
21		.242	.238	.233
22			.240	.235
23			.242	.237

ADJUSTMENT FOR TEST WEIGHT OF WHEAT AND PACKING EFFECT

The capacities found by these methods apply to the bins themselves, regardless of the kind of grain they may contain. For wheat, the chart provides the means of adjusting the capacities of the bins in measured bushels to quantity of wheat in legal bushels of 60 pounds that the bin will hold when the test weight per measured bushel is known, with due allowance for the packing effect of bulk wheat in deep bins as already noted.

(6) *Reducing capacity in measured bushels to legal bushels of wheat.*—The capacity of a bin has been found to be 6,540 bushels (chart reading for a circular bin of 18-foot diameter with a mean depth of 32 feet). The test weight of the wheat is 61 pounds per bushel. How many legal bushels (of 60 pounds) of wheat are there in the bin? On the diagonal line for 61 pounds test weight in the upper left-hand corner find the point opposite 6,540 on the scale for capacity (A), pass vertically to the reference line, and read the result, 6,965 bushels on the scale to the left (A').

For capacities greater than 10,000 bushels it will usually be necessary to divide the capacity into a sufficient number of parts to bring the fractional capacities within the limits of the chart. Thus, for the bin in example 2 above, the capacity was found to be 19,000 bushels. If the test weight of the wheat in this bin were less than 60 pounds per bushel, the number of legal bushels could be read as the sum of two parts of 9,500 bushels each, but for heavier test weights, say 62 pounds, it would be easier to work with the reading for 6,000 bushels capacity. The point on the reference line above the intersection of the diagonal line for 62 pounds test weight and the horizontal line for 6,000 bushels capacity or quantity (either scale, A or A', may be used) indicates 6,510 legal bushels of wheat. Three times this reading, 19,530, plus one-sixth of it, 1,085, gives 20,615 bushels as the estimate desired. ($19{,}000=3\times6{,}000+1{,}000$) computation from a formula (No. 4 on p. 8) gives 20,580 bushels. If the reading from the scale had been taken as 6,500 instead of 6,510, the estimate would have been 20,583, or 3 bushels more than the computed amount; if 6,525 had been read rather carelessly the estimate would have been 20,663 bushels, or 83 bushels more than the computed amount. The maximum error incident to difficulty in reading the exact position of the intersections on the chart is in this case about 0.4 of 1 per cent. With careful reading, however, the error is small.

The upper portion of the chart should always be used in preference to the lower portion. Slight errors in readings where the numerical quantities are large result in a percentage of error much smaller than when the numerical quantities are small.

ESTIMATING THE EQUIVALENT DEPTHS OF HOPPERS

The capacity of the hopper of a bin does not need to be estimated separately, but its depth should be reduced to its equivalent depth for the cross section of the bin. This equivalent depth is one-third of the depth for symmetrically shaped center-flow bin hoppers, and should always be included in the " depth of bin " used for reading the chart. For side-flow bins with irregular, or nonsymmetrical, hoppered bottoms the equivalent depth must be found by an indirect method, unless it is estimated by inspection.

(7) *Equivalent depth of bins with nonsymmetrical irregular hoppers.*—What is the mean depth of a bin 17 feet in diameter and 80 feet deep from bottom of hopper to rim, with a hopper rising 10 feet on one side? Put into the bin a carload of wheat of known test weight, say 59 pounds per bushel. A car of 72,000 pounds or 1,200 legal bushels will more than cover the hopper. Level the top of the wheat and measure accurately the distance from the rim down to the wheat. Assume, for example, that this distance is 68.8 feet. Now find the number of bushels capacity per foot of depth for 59-pound wheat in the bin. Using the diagonal for 20 feet depth and the vertical of 17 feet diameter, crossing to the diagonal for 59-pound test weight and moving upward to the reference line, the quantity for 20 feet of 59-pound wheat appears to be 3,750 legal bushels, or 187.5 bushels for each foot. Dividing the 1,200 bushels put in the bin by 187.5 bushels per foot of depth gives 6.4 feet, the equivalent or mean depth of the wheat in the bin. This gives (68.8 feet plus 6.4 feet) 75.2 feet for the equivalent depth of the bin. In subsequent estimates for this particular bin the mean depth of the grain is to be found by measuring the distance from the level surface of the grain to the rim of the bin and subtracting from 75.2 feet.

DEFINITIONS OF TERMS AND FORMULAS

Bushel: The standard (Winchester) bushel is a measure by volume and is equal to 1.2445 cubic feet. For trade purposes the legal bushel of wheat is set at 60 pounds. A standard bushel may contain more or less than a legal bushel, according to the test weight of the wheat, which is the number of pounds of a given lot of wheat in a standard bushel by measure.

Capacity of bin: Capacity of bin is the number of standard (Winchester) bushels of space it contains, or the volume of the bin in cubic feet divided by 1.2445 cubic feet.

Center-flow bin: A bin from which the grain is withdrawn from an opening located in the center of the bottom. A side-flow bin, on the other hand, has its outlet either in the wall or in the bottom near the side wall.

Cross section: As used in this circular a cross section is a horizontal plane through the bin and shows the shape of the bin. Most grain bins are of uniform cross section and regular in shape, circular or rectangular. Measurements are made inside the walls.

Symmetrical hopper: Hoppers, the sloping sides of which correspond to each other as in center-flow bins.

The readings from the chart may be checked arithmetically by substituting the actual bin measurements for the letters indicated in the following general formulas. The formulas may also be used without the chart in cases where the cross-sectional dimensions of the bin to be estimated are beyond the limits of the chart.

CIRCULAR BINS

$$(1)\quad C=\frac{3.1416\times D\times D\times H}{4\times 1.2445}=D\times D\times H\times 0.6311.$$

$$(2)\quad Q=D\times D\times H\times T\times 0.01103.$$

SQUARE BINS

$$(3)\quad C=\frac{F\times F\times H}{1.2445}.$$

$$(4)\quad Q=F\times F\times H\times T\times 0.01404.$$

RECTANGULAR BINS

$$(5)\quad C=\frac{L\times B\times H}{1.2445}.$$

$$(6)\quad Q=L\times B\times H\times T\times 0.01404.$$

BINS OF ANY SHAPE

$$(7)\quad Q=\frac{C\times T\times 1.0485}{60}=C\times T\times 0.01748.$$

In these formulas, C stands for capacity of bin in standard bushels; D for inside diameter of bin, in feet; H for equivalent depth of bin or of wheat in bin, in feet; F for length of side of square bin, in feet; L for long side of rectangular bin, in feet; B for short side of rectangular bin, in feet; Q for number of legal bushels of wheat a bin will hold, correction made for packing and test weight; T for test weight of wheat, pounds per bushel.

Formulas 1, 3, and 5 apply to bins holding any kind of grain; formulas 2, 4, 6, and 7 apply only to wheat.

In estimating the depth of grain in a bin it is well to remember that the accuracy of the measurement (and of the results) depends on the accuracy of the estimate of the position of a level surface of grain. It is not often feasible to level the surface of the grain, but all irregularities in the surface should be considered in measurements of depth.

Grain flowing into a bin will pile up. The shorter the distance the stream falls freely the steeper will be the slope of the pile. The peak of the top surface of the grain in a bin being filled is seldom at the center of the bin.

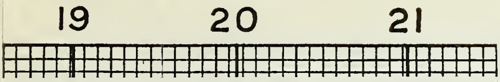
When wheat is withdrawn from a deep bin a depression is formed, the lowest point of which is directly over the outlet at the bottom of the bin.

Unless the surface of the grain is visible, the person making the measurement for depth should know whether grain was last put in or withdrawn from the bin and the location of the bin outlet.

To protect the chart from wear and tear incidental to office use it may be slipped under a glass table cover or mounted on a board or heavy cardboard and given a coat of shellac, which will permit cleaning with a damp cloth as often as necessary.

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1925

METER IN FEET.



-OF WHEAT IN LEGAL BUSHELS (60 LBS.)

-QUANTI- SCALE A

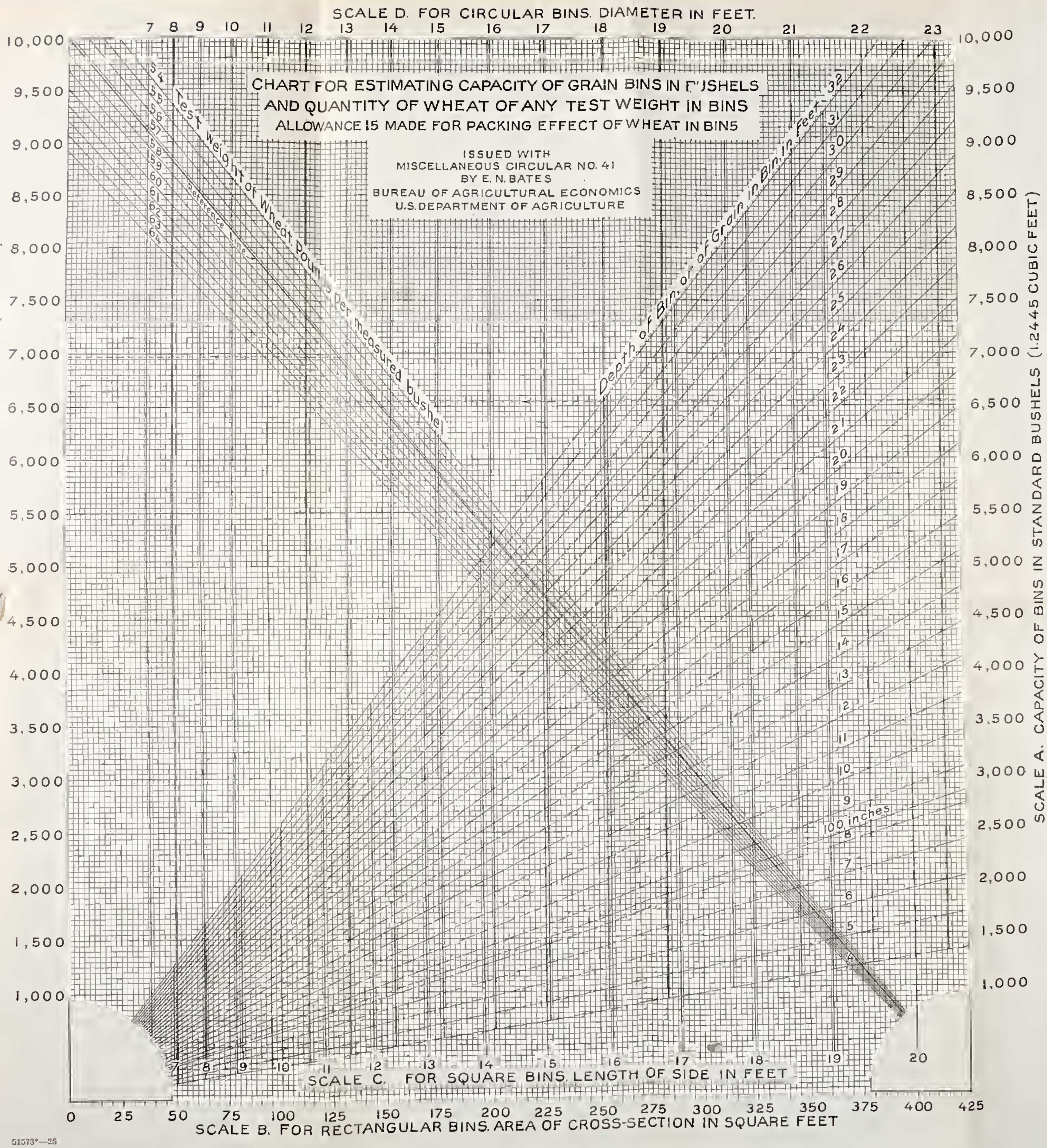


CHART FOR ESTIMATING CAPACITY OF GRAIN BINS IN BUSHELS
AND QUANTITY OF WHEAT OF ANY TEST WEIGHT IN BINS
ALLOWANCE IS MADE FOR PACKING EFFECT OF WHEAT IN BINS

ISSUED WITH
MISCELLANEOUS CIRCULAR NO. 41
BY E. N. BATES
BUREAU OF AGRICULTURAL ECONOMICS
U.S. DEPARTMENT OF AGRICULTURE